HOW TO

Mentor Undergraduate Researchers

Louise Temple
James Madison University

Thomas Q. Sibley
St. John's University

Amy J. Orr
Linfield College

A publication of the
Council on Undergraduate Research

Editors of this edition:

Louise Temple, PhD
James Madison University
Harrisonburg, VA 22807

Thomas Q. Sibley, PhD
St. John's University
Collegeville, MN 56321-3000

Amy J. Orr, PhD
Linfield College
McMinnville, OR 97128

Former editors, some of whose work has been carried forward:

Carolyn Ash, PhD
Emeritus, California Institute of Technology
Pasadena, CA 91125

Shenda M. Baker, PhD
Harvey Mudd College
Claremont, CA 91711-5990

Contributors:

Herb Childress, PhD
Boston Architectural College
Boston MA 02115

Gloria C. Cox, PhD
University of North Texas
Denton, TX 76203-5017

Janice DeCosmo, PhD
University of Washington
Seattle, Washington 98195

Susan Brown Eve, PhD
University of North Texas
Denton, TX 76203-5017

Ronald G. Kander, PhD
James Madison University
Harrisonburg, Virginia 22807

Stephen Kercher, PhD
University of Wisconsin at Oshkosh
Oshkosh, WI 54901

J. A. Kinkead, PhD
Utah State University
Logan UT 84322 1450

Julio C. Rivera, PhD
Carthage College
Kenosha, Wisconsin 53140

Merle Schuh, PhD
Emeritus, Davidson College
Davidson, NC 28036

Naomi Yavneh, PhD
University of South Florida
Tampa FL 33620-6912

Gregory Young, PhD
Montana State University
Bozeman, Montana 59717-2560

Debra A. Zellner, PhD
Montclair State University
Montclair, NJ 07043

How to Mentor Undergraduate Researchers

Louise Temple, PhD, James Madison University
Thomas Q. Sibley, PhD, St. John's University
Amy J. Orr, PhD, Linfield College

Council on Undergraduate Research

All rights reserved. We encourage you to make good use of the material within. Be reminded, however, that prior written permission from the Council on Undergraduate Research is required before any part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form, by any means, electronic, mechanical, photocopying, recording, or otherwise.
©2010

ISBN: 0-941933-39-3

Council on Undergraduate Research
734 15th Street NW, Suite 550
Washington, DC 20005
Phone: 202.783.4810
Fax: 202.783.4811
www.cur.org
cur@cur.org

This is part of the CUR "How To" series of booklets published to help faculty and other researchers create research and learning opportunities for students. The specific views expressed in CUR's "How To" series are those of the authors. CUR hopes that the series will be used to spark discussion of best practices as well as to provide a road map for those embarking on research with undergraduates.

Photo on cover: Terri Hogue working with student Bridget Navarro. Dr. Hogue is an Associate Professor in the Department of Civil and Environmental Engineering at UCLA and Director, NSF Science and Engineering of the Environment of Los Angeles (SEE-LA) GK-12 Program.

EDITORS OF THIS EDITION:

Louise Temple, PhD
James Madison University
Harrisonburg, VA 22807

Amy J. Orr, PhD
Linfield College
McMinnville, OR 97128

Thomas Q. Sibley, PhD
St. John's University
Collegeville, MN 56321-3000

FORMER EDITORS, SOME OF WHOSE WORK HAS BEEN CARRIED FORWARD:

Carolyn Ash, PhD
Emeritus, California Institute of Technology
Pasadena, CA 91125

Shenda M. Baker, PhD
Harvey Mudd College
Claremont, CA 91711-5990

CONTRIBUTORS:

Herb Childress, PhD
Boston Architectural College
Boston MA 02115

Gloria C. Cox, PhD
University of North Texas
Denton, TX 76203-5017

Janice DeCosmo, PhD
University of Washington
Seattle, Washington 98195

Susan Brown Eve, PhD
University of North Texas
Denton, TX 76203-5017

Ronald G. Kander, PhD
James Madison University
Harrisonburg, Virginia 22807

Stephen Kercher, PhD
University of Wisconsin at Oshkosh
Oshkosh, WI 54901

J. A. Kinkead, PhD
Utah State University
Logan UT 84322 1450

Julio C. Rivera, PhD
Carthage College
Kenosha, Wisconsin 53140

Merle Schuh, PhD
Emeritus, Davidson College
Davidson, NC 28036

Naomi Yavneh, PhD
University of South Florida
Tampa FL 33620-6912

Gregory Young, PhD
Montana State University
Bozeman, Montana 59717-2560

Debra A. Zellner, PhD
Montclair State University
Montclair, NJ 07043

How to Mentor Undergraduate Research

Table of Contents

Preface ix

Introduction: The Importance and Value of Mentoring Undergraduates 1

Part I Fundamentals of Mentoring 5

- The Elements of Mentorship 5
- Key Traits of Mentoring 5
- The Rewards and Challenges of Mentoring 6
- The Varying Abilities of Students 7
- Understanding and Establishing Expectations 8
- Multiple Models 10
- Communicating Research 12

Part II Mentoring in Specific Disciplines 14

- Lab-Based Sciences 14
- Engineering 17
- Mathematical Sciences 18
- Fine Arts 20
- Humanities 22
- Social Sciences 23

Part III Other Important Considerations 33

- Interdisciplinary Research 33
- Graduate Students as Mentors 34
- Letters of Recommendation 36
- Preparation for Graduate-School Applications 37

Conclusion 39

Appendices

- A: Frequently Asked Questions 40
- B: Student Quotes 42
- C: Mentoring Tips 44

Preface

This updated *How to Mentor* handbook reflects many changes over the last decade in the scope and extent of research opportunities for undergraduates in the United States. We have drawn on the timeless advice and wisdom present in the first edition, 2002, which was edited by Carolyn Ash Merkel and Shenda M. Baker. Reflecting the current expansion of CUR into all undergraduate disciplines, in this edition we have called on experts in a variety of different fields to expand the handbook's usefulness across all areas of undergraduate research endeavors. In particular, the Social Sciences section reflects not only doing research in the social sciences, but also on the fact that mentoring is a social process. (A larger treatise on this subject can be found on the CUR Web site, *http://www.cur.org/socializing.html.*) Some unavoidable redundancies in this handbook reflect the practices and values held in common across disciplines.

Louise Temple, Tom Sibley, and Amy Orr

Introduction: The Importance and Value of Mentoring Undergraduates

Serving as a mentor to a young scholar is an important and rewarding role. Many opportunities exist for undergraduates to conduct a variety of research, scholarly, and creative projects with faculty at colleges and universities, as well as with professionals in other settings. Mentors, whether faculty members or other individuals, are pivotal in ensuring the success of the student experience. They teach a variety of applied skills, methods, and techniques. To help students sink their roots into the culture of the discipline, mentors coach students to develop new ways to approach questions and encourage them to think about and reflect on the research. Through excellent mentoring, students are invited into the community of researchers and scholars as colleagues. Mentors pass on the nature and culture of their areas to the next generation. They help students to develop critical-thinking skills, along with hands-on experience in the creative process.

Mentors play a significant role in providing intellectual stimulation for student scholars. Through working on a research project of mutual interest, students become colleagues with their mentors and any other members in the project. As they engage with the research, participate in discussions, and meet with colleagues, students learn to ask questions and to offer their ideas. They develop confidence in their abilities. The process fosters their curiosity—they delve more deeply into their projects and often develop a hunger for further intellectual explorations. Sometimes the relationships formed through scholarly collaboration last long after the student completes his or her degree and ultimately develop into strong professional interactions.

In learning first-hand the nature of their subject, students apply what they have learned in the classroom to real-world problems or unresolved and often ill-defined questions. The students have, perhaps for the first time, the opportunity to try out new ideas, ask new questions, solve unsolved problems, or develop new devices or processes. They learn to work with the ambiguity of not always knowing the next steps or they learn that one question may lead to many new questions.

Because undergraduate research is an apprenticeship, the mentor teaches through example and coaching, and students learn by doing. Delving into a project and exploring the unknown provide the best learning environment for many students. Students develop critical thinking and analytical skills. As they take intellectual ownership of a project, they often develop the ability to make research decisions, learn the questions to ask, choose new directions, and gain the confidence to ask new questions and even question the mentor.

Mentors train the next generation of researchers and scholars. The mentoring experience provides important advantages to the student that will last long after the program is completed. As students are immersed in their projects, they begin to develop fluency in the language and concepts of the field through informal

interactions and formal presentations—the ones they hear and the ones they give. They absorb the ethics and practices of the discipline, and they learn the methods and skills necessary for the field.

Further, mentoring is extremely important in helping undergraduates to develop their career focus. Students gain important insight into the kinds of careers available and potentially attractive to them through their undergraduate research experiences. At the same time, and equally as valuable, students who were convinced they wanted to pursue a research career may determine that research is not for them. It may be considered a success when a student gains such personal insight before he or she has invested several years in graduate school. Mentors play a key role by providing advice, making observations about such matters as the progress of the research and students' fitness for a research career, and giving feedback. Students gain personal insight into the kind of work they enjoy. Undergraduate research thus may recruit students into a field or retain them in a scholarly career track.

Through undergraduate research, students also become members of the community of scholars. As students talk with their mentors, other faculty members, and other students, they develop that sense of community. The intellectual stimulation brought by sharing ideas and research experiences deepens students' academic pursuits. They can observe the life of a researcher and glimpse their own futures if they should choose academic life. However, undergraduate research gives students valuable experiences that will benefit them no matter what they choose to do for a career. College graduates with experience in understanding and conducting research will be able to function more effectively as leaders.

According to Mabrouk and Peters,* students report the most important aspect of their undergraduate research experiences is the relationship with the mentor. From the students' perspectives, the most valuable characteristics in mentors include "the advisor's knowledge about the project, [and his/her] enthusiasm, availability, and patience." These characteristics are more valuable to the student than "an advisor [who] is intellectually brilliant, has external research funding, works at the frontiers of knowledge, or is well known professionally."

In the final analysis, undergraduate research should provide a high-quality educational experience for participants. Students draw from their classroom knowledge to tackle new problems. They begin to understand their discipline as it is practiced, often a far cry from what they envision while sitting in a classroom or reading from a textbook. This understanding is important; it may be a turning point in a student's decision about whether or not to continue in the field of their project. Students have the potential to become intellectual partners in the projects on which they work, taking ownership of their work, whether it is their own project or they are involved in part of the mentor's ongoing work. The mentor's role is to ensure that these goals are met.

---

* Mabrouk, P.A.; Peters, K.* *CUR Quarterly* 2000, 21, 25–33. "Student Perspectives on Undergraduate Research (UR) Experiences in Chemistry and Biology."

The purpose of this handbook is to provide encouragement and advice to those who may be mentoring students for the first time and also to reinforce the experiences and provide new insights for those who have already mentored undergraduates. For simplicity's sake, we generally use the term "research" in the main body of the text, even though in different disciplines other terms such as "scholarship" or "creative project" may be more appropriate. The main body of this publication deals with common concerns. Some later sections address issues specific to particular disciplines, but we encourage readers to peruse sections outside their own disciplines for ideas, since undergraduate projects range as widely as do mentors' academic pursuits.

Part I: Fundamentals of Mentoring

THE ELEMENTS OF MENTORSHIP

Every career path blends three forms of thinking—content knowledge, logistical management, and a sense of purpose and strategy. We can think about these as *what we do, how we do it,* and *why we do it.*

Higher education has traditionally focused on conveying the content of its departments—the knowledge base, theories, and analytical practices that define academic disciplines. These bodies of content are what our students exhibit in their tests, essays, and projects. But all too often we lose sight of the other two components of intellectual life: the day-to-day logistical management required to sustain a life of the mind, and a sense of the purposes that drive us and the strategies we use to define our particular niche within the academy.

It is crucial for our discussion that we as academics separate these goals and their three related professional activities. *Teaching* is the practice that we use to convey and support the intellectual content of our fields; we communicate knowledge, principles, theories, and methods, and we set out pedagogical opportunities for our students to engage with that world of ideas. *Supervising* is the practice of helping our students manage the mundane but crucial daily tasks that make scholarship possible—organizing field notes, managing electronic files, finding archives, learning analytical software, writing draft reports. Finally, *mentoring* is the work of exposing our students to our own interests and enthusiasms, introducing them to a larger community of scholars, and helping them work through the emotional questions that might result in their adopting a way of life. As mentors, we are *role models* in the most sociological sense: We are modeling (by living and narrating) a role (as a scholar, researcher, and teacher), so that our students can try that role on for themselves to see how well it fits.

Mentorship, then, helps students think about their potential future lives as professionals in a discipline or an interdisciplinary field with their accompanying content and logistics. If they can imagine themselves—in detail—as professionals and researchers, they can more easily develop the internal motivation required to realize such goals.

KEY TRAITS FOR MENTORING

There are some key traits in mentors that are especially important to encouraging collaborative work with our students. They include:

- **Forwardness.** Our students may well be hesitant about approaching us if they are interested in doing scholarship. They know that they don't know much yet and may feel inadequate or in danger of being dismissed. And they certainly know that they don't yet know enough to take on fully professional work. But with undergraduate research projects, we as faculty are in charge. We can recruit students in whose eyes we see the glint of pleasure in the ideas of the classroom; we can reach out to students who may not yet feel capable of reaching out to us.

- **Persistence and repetition.** Nothing is easy the first time ... or, perhaps, even the fourth. The ongoing contacts with undergraduates during research projects allow us to give students the opportunity to struggle and eventually to emerge from those struggles with a hard-won success. And inviting students into our intellectual world allows them to see us struggling with the framing of a new problem, with the management of inevitable setbacks. It takes scholars off pedestals and allows undergraduates to see us as workers and thinkers not unlike themselves.
- **Emotional honesty.** We all entered our career paths because of some particular motive, often hard to state rationally but still at the core of why we do the work we've chosen. There are parts of our work that enliven us and other parts we find frustrating or tedious. Our being open about the joys and challenges we find in our work will help our students see how they might partake of the particular pleasures of our discipline.
- **Recognizing and locating alternative mentors.** As students grow and become more focused in their work, they may well want to take their scholarship into areas with which we're less familiar or less capable of strong guidance. If students have been working and presenting along with us, they're becoming part of our professional network, and we can work with them to find an intellectual guide more closely fitted to their specific interests.

THE REWARDS AND CHALLENGES OF MENTORING

Mentoring students can be rewarding for faculty members in a variety of ways. Mentors gain personal satisfaction from working with students. They often enjoy training the next generation, watching students mature intellectually and knowing that they played an integral part in that process. Students can bring a fresh perspective to faculty members' work because they have not developed biases about what should or should not happen, and they might ask the simple questions that are often overlooked when faculty have been immersed in the research for a long time. Faculty build collegial relationships with these young people, which often last for many years and become professional collaborations.

A possible benefit for mentors in some disciplines at smaller institutions may be increased research productivity. For faculty at large research universities, mentoring brings them one-to-one interaction with bright and talented students who have not yet decided on graduate school. Increasing numbers of young faculty choose to become mentors of undergraduates because they were set on their own career paths by research experiences as undergraduates, and they want to pass on the richness of the experience to others. Further, the mentor/student relationship provides a creative and dynamic environment for faculty and for students. Through undergraduate research, students gain great advantages and mentors reach far and touch many.

At the same time, mentoring students can be challenging. The evolution of a good mentoring relationship, for example, starts with a significant investment of time by the mentor. Even if the project is student-initiated, the student initially will need a

significant amount of direction and suggested methods for approaching the project. For a mentor-initiated project, the student additionally needs to understand the goals of the project and how it fits into broader research in the field. The first week or two is crucial to establishing the mentoring relationship and getting the project under way. This interaction provides meaning and motivation for the work and should produce understanding of the mentor's expectations.

The interactions between the mentor and the student scholar are critical to success. The mentor must communicate frequently and clearly about the project, the student's progress, and the expectations. Mentors must encourage students to persist when things don't work well. The mentor needs to budget time to ensure the student can learn any needed additional skills or techniques to carry out the project as it develops.

As the student matures, the mentor's time commitment should lessen. The successful student will begin to take ownership of the project and suggest new means for resolving difficulties or new directions for the project. A good mentor will allow the student to try new things that seem unlikely to work, but will guide the student back before the expense of time or money becomes too great. Sometimes these forays into blind alleys, and subsequent recovery, reflect the learning and thought processes required to do quality research.

Another challenge is the reluctance of some students to ask questions. They labor under the notion that asking questions reveals a lack of knowledge that their mentors think they should have. Yet not asking questions can cause students to miss out on important information they need to continue a project. If they get behind in their work and don't talk about a problem, they may try to work it out for themselves. This effort can cause them to become frustrated and discouraged. Mentors play an important role in encouraging students to ask questions and by ensuring that they have the information they need.

Students may also be hesitant to discuss problems that arise, particularly personal issues involving the mentor. They want (and need) the mentor's recommendation for future opportunities and applications. They sometimes think that if they assert themselves, they will fall from favor and lose the recommendation, so they try to get through the experience the best they can. Mentors often are unaware that the students are unhappy, and thus the mentors cannot address the situation. The most effective mentors keep communication channels open and encourage students' comments about how things are going.

THE VARYING ABILITIES OF STUDENTS

Undergraduates come to their first research opportunities with a wide range of previous knowledge, experiences, and talent. Many students possess intellectual knowledge but lack social maturity. Those who have little practical life experience and little or no work experience in a professional work environment may be less confident than other students. Some are just developing their critical thinking and analytical skills. Perhaps most students who have grown up within a highly structured

educational system have learned not to take the next step until they are told to do so. They also may not know how to analyze a process or ask questions on their own.

Other students may have confidence but little experience and may make inappropriate decisions about the research or procedures. On the other hand, some students will come with experience or with a natural affinity for doing research, will exhibit maturity, and can function at the level of a graduate student. However, all students, regardless of their preparation, tend to approach their undergraduate research with a passion for the field, great enthusiasm, and high expectations for the work they will do.

Mentors must accommodate to students' varying levels of preparation, skills, and abilities. If a mentor assumes that the student has more experience or knowledge than the student in fact does, the mentor may provide insufficient support in the beginning stages of the project. Students can become overwhelmed when they do not receive the support they need, and as noted above, often are reluctant to ask for assistance. If progress becomes very slow, and they are unsure of what they are doing, students may become discouraged.

It is important to remember that undergraduate research students are not graduate students. Some are as capable as graduate students when they begin; many are not. They generally will not have developed the skills and abilities of graduate students, and they usually do not have the knowledge base. However, they do have the potential for learning and great enthusiasm for what they are doing. Mentors should seek students who can rise to the challenge offered. It is up to mentors to set realistic goals for projects and then to work closely with students until they can work more independently.

It is important to remember that undergraduates may require more direction and focus than graduate students. They need a clearly stated goal, a suggested first means to achieve the goal, and, if appropriate, a timeline setting out expectations. Some students will be able to take ownership of a project sooner than others, depending upon the level of their skills and experience. Students should acquire some insight into what a career in research would entail, from the daily activities to the planning and, if appropriate, discussions required for interdisciplinary research. The technical training needed should be taught throughout the course of the project, but the ultimate development of the students is based on establishing the proper mentality and methods of research.

UNDERSTANDING AND ESTABLISHING EXPECTATIONS

Students often think that research should proceed like classroom experiences, where they do a prescribed set of activities and analyze them with already-developed approaches. Often students become frustrated when they get unexpected or disappointing results during research. As a result, they try a few things and then give up. They are unable to "think outside the box." Alternatively, some students make random attempts, hoping to stumble upon something. The importance of careful, and sometimes time-consuming, attention to details and options needs to be

stressed. Trying slightly different approaches again and again is a foreign concept to many students. Although they are a tenacious bunch in general, they tend to be more timid faced with unknown problems. A mentor's encouragement and willingness to let undergraduates try and fail before stepping in with a solution provides a good lesson in trial and error that students should learn.

Students often expect to achieve something significant by the end of their projects, and sometimes they do. More often, though, the slow pace of their research surprises them. They sometimes think they are not doing enough or that the mentor and others will be disappointed that they are not accomplishing more each day or week. If unwelcome surprises bring the research to a halt, students often become discouraged. Mentors must encourage students to persist through these periods and to value the importance of quality, not necessarily quantity, of progress or results alone.

Students enter undergraduate research with a focus on the product or outcome of the project. They expect to learn research skills, methods, and techniques, but often focus on the final answer or accomplishment. They are often surprised at the personal insight they gain through the process itself as they learn what kind of work they like to do and the kinds of professional interactions that are satisfying and interesting to them. The confidence they gain is a bonus most of them did not envision. The mentor can also help in this regard by getting students to periodically reflect on what they are learning in addition to the research results.

At the end of a research experience, the undergraduate should have learned what it is like to work on, but perhaps not completely solve, an interesting and original question Mentoring students is first and foremost an educational activity. For most students, undergraduate research is an introduction to research. It is important to give students projects for which they can take intellectual ownership. While publication in the refereed literature is a worthy goal, the success of an undergraduate project does not depend upon such publication. Some projects, although worthwhile as undergraduate projects, don't have such potential. In others, the student may not be able to make sufficient progress to achieve publishable results in the limited time available for the research.

However, if a mentor expects too little of a student and does not provide a challenge, the student has nothing for which to reach. In particular, mentors should never use students as "extra pairs of hands" for routine tasks. In such cases, the opportunity to stimulate the students is lost, and students may be quickly disillusioned.

One of the more difficult tasks that a mentor must undertake is balancing the level of encouragement versus discipline if the student is not making progress. Depending on the student, the response of the mentor can vary. Some students seem to be motivated by a hard line such as, "You really need to focus and get this done. The current rate of progress is unacceptable." The mentor must be clear about exactly what aspects of the work are unacceptable. Is the student being a social butterfly rather than getting the job done? Is there a fundamental misunderstanding of the expectations or goals?

For other students, such a pointed response would discourage them. For them a better response comes from a gentler approach such as, "Is there some issue impeding your efforts I don't know about?" Give the student encouragement and build on the earlier enthusiasm. The most effective response is never exactly the same for any two students.

MULTIPLE MODELS

Research with undergraduates has been successfully accomplished in a variety of ways. Perhaps the most common, and some would say the gold standard, is a one-on-one partnership between a mentor and one student. In this one faculty member-one student model, the progress of the student can be closely monitored and the stages to independence carefully gauged. Student feedback on his/her understanding of methods and subject matter can occur frequently, minimizing the time spent working fruitlessly under misconceptions. The opportunity for impact on students and mentors in such partnerships cannot be understated. Both the rewards for and the responsibilities of the mentor are great. Depending on workload and type of research, a faculty member might mentor more than one student in this fashion, with each student working independently on his/her own project.

Teams of students are often used to share the workload and practice teamwork skills. Teams can be a very successful and efficient approach when long procedures are essential but these cannot be performed by an individual student, given the other demands on undergraduates' time. Teams are also valuable as a means to give more students research opportunities. Issues with team-based research are the same as with any team projects, including the relative preparedness and commitment of individuals, their workloads, and personalities. It is exceedingly important in team projects to develop clear guidelines, expectations, and consequences. This process is most successfully done in consultation with the team members.

Several examples of entire classes performing original research have been demonstrated in the sciences. The Science Education Alliance, sponsored by the Howard Hughes Medical Institute, is the largest effort of this type, in which hundreds of entering college freshmen are discovering and analyzing bacterial viruses. A number of science educators, on a smaller scale, utilize upper-level, specialized courses with labs of a dozen or more students as venues for performing original research. Of course, such labs add to the workload of the faculty member, who must remain quite nimble, since challenges, failures, and surprises are the norm in research. A substantial body of evidence is emerging that indicates the transformative power of original research for students, even when it is performed in groups.

The specific goals of an individual or team in research might be a bite-size portion of a larger research project developed by the mentor. Within such a defined topic, students still have the opportunity to come up with new ideas and original testable hypotheses. Particularly in the sciences, this model is essential to garnering financial support for the research, and the mentor must conceive a research question that can be answered in small projects attainable by undergraduate researchers in fairly short time periods.

Certain subject areas, particularly if the expense of the research is low, are amenable to students' approaching faculty with their own ideas, originating from their own observations, imaginations, readings, or class experiences. Student-originated topics are valuable in certain disciplines in which original ideas can be explored with only human resources and do not require specialized equipment and reagents.

The timing of research can vary, as well. For example, a concentrated summer experience presents certain opportunities and challenges, while work during the academic year is mixed with other obligations. A thesis may represent several years of varied experiences.

Summer projects allow students and mentors to immerse themselves in the research without the distractions and interruptions of courses and other activities the academic year involves. Students can delve into a problem, and they can take time (or learn) to reflect on the work. They can step back from the research to review where they are relative to their original goals. However, summer research requires funding, which restricts the number of students who can benefit from this opportunity. Also, many faculty members see summers as the key time for their own research, and student research may or may not fit the mentor's program.

If possible, it is important for a mentor to be flexible about when a student starts a summer research project. Some students are burned out at the end of a term and need a break before starting a research project. For other students, research revitalizes them, and they want to get into the project right away.

Summer research is often part of a structured program that includes activities to enhance the research experience. Some students come to summer research programs expecting to be "trained" and to have many social events. Certainly, training and socializing are aspects of any research program, but students need to understand up front that the main activity of a research experience is the research itself.

In projects during the **academic year**, the pace of the work is dictated by the myriad other demands on student and faculty time and attention. Students may work for pay or academic credit or they may volunteer. In any case, they usually cannot spend more than a few hours a week, and the time spent competes with classes, homework, and extracurricular activities. Mentors must allow their student scholars a flexible schedule, while still setting clear expectations about the effort to be expended on research. Students feel increased pressure at certain periods in an academic term, such as during exam periods or as the term end approaches and papers and projects for other courses are due. They may be less productive at such times than at other periods. For some students, doing research is the antidote to the stress of homework sets, papers, projects, and assignments. Occasionally a student prefers to do research and procrastinates on other responsibilities. In that case, research becomes the distraction to academic progress. If a student is doing research for academic credit, it is very important for the mentor to articulate clearly the time and effort requirements for the grade, but advise the student to balance research with other academic demands.

Senior theses represent a capstone for an undergraduate research project, and mentors have critical responsibilities in shepherding a senior-thesis student. The

interaction between student and mentor becomes more like a graduate student-advisor relationship as the mentor guides the student toward the thesis.

If a student and mentor decide to expand a research project into a senior thesis, the relevant campus constituencies (mentor, student, academic advisor, registrar, department, etc.) must agree up front to allocate sufficient academic credit to allow the student enough time to do the research and write the thesis. Mentors must clearly communicate to the student the amount of time and effort the research will require during the academic year. Departmental or institutional guidelines may dictate the amount of credit a student can earn. If not, the project should be identified early in the fall, if at all possible, to provide a year-long experience.

Mentors must help the student design a manageable project, and they should coach the student in coordinating his or her time to get the research to the writing stage when appropriate. Mentors should set realistic deadlines for completion of sections of the thesis. The student should have a set time—at least weekly—to meet with the mentor. This is particularly important because students are often tempted to use less structured time to catch up on other academic activities during busy periods. Weekly meetings and progress reports can help them maintain focus.

COMMUNICATING RESEARCH

Since scholarship not communicated is essentially scholarship not done, communication is a critical aspect of the undergraduate research experience. Mentors can encourage students to develop excellent written and oral presentation skills by giving them opportunities to present their work not only to peers within their disciplines, but also to colleagues in other fields and to the public. These can be oral presentations, posters (with ample time to discuss them with colleagues), abstracts, reports, or longer papers.

Having students rehearse their final presentations several times before they give them provides several positive outcomes. First, this forces them to organize their thoughts and material. It also helps students to think critically about what they have accomplished and may help ensure the continuation of the project after they leave. They often realize further steps they or their successors can take in the project that they might not have considered without the reflection done for the talk.

Working with students on their oral presentations also provides opportunity and incentive to teach the students to think about their work objectively, without placing a value judgment on it. For example, it is more useful to say "the lack of statistical significance indicates that there may be additional factors we need to consider," rather than "I got horrible data." Similarly, the statement "the approach I tried this summer shows that water cannot be used as a solvent for this reaction, even if it would result in less organic waste" is more informative than "my project bombed." This approach focuses students on what they actually learned and may diminish their perception that they are unable to do research. Such reflection will enhance their development as professionals.

Rehearsed presentations also are better presentations. Students need to try out their explanations on the mentor, friends, and others. This will allow students to come to the speaking experience with more confidence. Working on refining their talks also can ensure that they complete the presentation in the allotted time.

Several opportunities for student presentation are available, and mentors should encourage students to apply for opportunities to present their work. Some examples of presentation venues include the following:

- The Council on Undergraduate Research offers students an opportunity to participate in the annual "Posters on the Hill" session in Washington, DC, each spring to present their research to members of Congress and their staff members.
- Many institutions send students to the National Conference on Undergraduate Research, which is held at a college or university each spring. This multidisciplinary conference gives students the opportunity to present their own research and also allows them to see how research is carried out and reported in other disciplines.
- Regional undergraduate research conferences also offer the opportunity for students to give their presentations, and mentors should seek to have their students participate.
- Mentors should also, if the research is appropriate, encourage their students to present posters or talks at meetings of professional societies.
- Many colleges and universities hold undergraduate research symposia to give students the chance to present their research to the campus community. A summary description of many of these symposia is on the Members section of the CUR website, www.cur.org.

Mentors can foster technical writing skills by coaching students to prepare a final paper. The form of the paper depends on the nature of the project. For suitable projects, the paper can be written as though for publication in a refereed journal and, if warranted, submitted. However, publication is not the only measure of success. Other papers can profitably have the next student researcher as the intended audience. In any case, the final result must be seen as more than a classroom exercise in which students show they have learned what the professor already knows. Mentors might require students periodically to write summaries of the progress of their projects and use the reports as a tool to help students step back from the details of the work and evaluate progress toward the research goals.

Professional societies provide a number of resources for guiding students in preparing talks, papers, and posters. Mentors should check the Web sites of their professional organizations. Mentors also are welcome to use or adapt the material in "The SURF Talk Book," developed for the California Institute of Technology's Summer Undergraduate Research Fellowships program, as well as the SURF writing guidelines (www.surf.caltech.edu/Fellows/SURF_talk_book.pdf).

Part II. Mentoring in Specific Disciplines

LAB-BASED SCIENCES

Mentors in a laboratory setting, especially beginning faculty members, need to keep several questions foremost in their minds, including:

- What best practices already exist at your institution and in your academic department?
- What do you expect students to accomplish in the laboratory?
- What do you expect students to gain from the experience in the laboratory, whether they aspire to graduate-level research or not?
- What differences exist between your experiences as a graduate student and reasonable expectations of undergraduate students in a research laboratory?
- How should you mentor students to optimize your time and your students' time?
- Is student research part of your research program or an independent project?
- What are the safety guidelines, procedures, and training needed?
- What laboratory-safety procedures and policies apply within your department?

Selecting students and setting expectations. Students' performance and ability to produce reliable results will depend on their background in the academic discipline, ability to think and work independently, industriousness and self-discipline, interest in the project, the degree to which they understand the experimental techniques and the problem they have been assigned, and the expectations of the mentor.

Some qualities a mentor should look for in prospective undergraduate researchers are scientific inquisitiveness, ability to work independently, and range of previous experiences. The best way to spot these characteristics is to see them first-hand in students whom a mentor might be teaching in the laboratory part of a standard curricular course. If this circumstance does not exist for a mentor, then one should consult with faculty colleagues regarding outstanding students whom they have taught and observed in their standard laboratory courses. As students' laboratory performance is not necessarily directly related to their ability with formal coursework, mentors should look beyond course grades or other formal assessments when trying to identify potential undergraduate researchers.

Since undergraduates generally will have taken only about four courses in their academic major by the end of the sophomore year, mentors often hesitate to accept first- or second-year students to do research. It is understandable that for some types of research, students need numerous background courses that they won't have accumulated until their junior or senior years, in order to be effective in the laboratory. Yet a mentor should not rule out accepting other students. Instead, mentors should make a special effort to design research sub-projects of their main research that require less coursework and student maturity and thus can be performed by students with less preparation. Moreover, if such less-experienced students can be motivated to continue

doing research with the same mentor for additional years, they will be more effective researchers when they become juniors and seniors, and their presence can provide the continuity between students having no experience and a lot of experience. This may pay big dividends for students and the mentor in the long run.

Mentors need to remember, though, that undergraduates have limited time available for research. A typical student doing research for one course credit generally cannot be expected to spend more than 12 hours in the lab per week, and in the laboratory such a student is probably only one-third to one-half as effective as a graduate student would be. Thus, a typical undergraduate will be able to accomplish roughly only about ten percent of the output of a graduate student who works full-time on research. This is true for even the brightest and most effective of undergraduates.

Often mentors can anticipate the results of particular experiments and the way in which the results will add to their growing understanding of a particular research problem. Yet it is important for the mentor to avoid emphasizing any expected results, lest the students become biased enough to shade the interpretations of the actual results in favor of the anticipated results.

Laboratory routines. Depending on the backgrounds of students, mentors likely will want to have a protocol book appropriate for their laboratories that describes routine laboratory procedures. These may include, for example, the preparation and interpretations of graphs and charts, the use of sterile techniques and an autoclave, the proper methods for using small and large equipment, the preparation of solutions, and routine concentration and dilution procedures and calculations. Procedures in a biology laboratory might also include basic molecular-biology techniques, such as use of restriction enzymes and DNA isolation and manipulation; and basic microbiology techniques such as proper growth conditions for liquid cultures and organisms and techniques for plating single colonies.

Rather than actually writing a laboratory-protocol book themselves, mentors can have more-experienced research students write various descriptions and ultimately prepare the actual laboratory manual. This approach will spare mentors considerable personal time and provide students the additional useful experiences of organizing their thoughts, writing scientific descriptions, and learning to communicate scientific terminology and descriptions concisely.

Following are some suggestions to foster time-efficient ways for undergraduates to conduct research projects. Encourage students to find blocks of several hours for doing research rather than isolated single-hour periods between classes. Set up a work schedule with students and ensure that they adhere to it. If necessary, prior to a new experiment a mentor should meet with students to discuss procedures and possible problems that they might encounter. This approach is preferable to waiting until the student actually encounters such problems while running the experiment and is forced to waste time in trying to find the mentor for consultation. Many experiments require only a manual set-up, after which they run by themselves with only limited, occasional human monitoring. The mentor should assign students to read literature

references during the time that such experiments are running. Students trained in literature research can be assigned to try and find appropriate papers to read. During periods of lower lab activity, students can be analyzing previous data. A mentor should emphasize to students that they should plan well in advance and do all essential preparatory steps—such as preparation of solutions, equipment set-ups, and instrument warm-ups—prior to doing the actual experiments.

Lab organization, cleanliness, and good record-keeping are essential to running a successful lab experience. For instance, nothing is more discouraging during an experiment than for the experimenter to be unable to find a vital piece of equipment or a specific piece of glassware that is clean and ready for use at a crucial moment. To overcome such problems, the mentor, with input from the students, should plan the organization and layout of the laboratory.

Once the students have such a plan, they should then be assigned the tasks of setting up the laboratory and putting all glassware and routinely used equipment into the appropriate drawers and shelves in accordance with the plan. The lab plan should be posted in the laboratory, showing where all research equipment and glassware are located for ready access. Each student should accomplish a particular weekly task to maintain the functionality of the laboratory for everyone. For instance, students can ensure the availability of an adequate supply of deionized water, commonly used chemicals, and clean, autoclaved glassware. Students should rotate through the tasks to ensure equitable assignment of tasks.

Getting students involved. In most cases a mentor will need to spend the largest amount of time with students during the early stages of the research. Early on, the mentor generally needs to conduct actual experiments with students and/or at least show students how to correctly use particular instrumentation. Students who try to teach themselves these things invariably need more time, and they may miss important points about doing experiments that will affect (possibly adversely) the outcomes of future experiments. Assigned readings explaining the instrumentation and experimentation techniques can help prepare students for their first skirmish using instruments and techniques in experiments with the mentor.

In an established research program with students having different levels of experience, more-experienced students can show newer students how to operate equipment and can explain routine experimental procedures. In addition to introducing instruments and laboratory techniques, students need to understand the research they will be doing and how the research ties into the broader research field. Assigned readings can help students achieve such understanding. A mentor may need to write some of these readings to cover issues specific to particular research or to help students understand more-advanced readings.

The number of students that a mentor should seek to have in a research group varies considerably, depending on the time the mentor has available to be actively involved in the research, the size of the laboratory space, the availability of equipment, and the number of well-chosen research projects established by the mentor. There are

numerous trade-offs associated with mentoring a large number of students. In general, more students can accomplish more work. In addition, they may develop a higher level of camaraderie and can learn more from each other. However, faculty with too many students unduly burden themselves. They may have fewer one-on-one interactions, and individual students (especially less-motivated ones) may accomplish less.

Through experience, mentors discover how many students are appropriate for them. The research group's size and dynamics should provide some free time for the mentor and should allow students to maintain a feeling of satisfaction and understanding of their projects, to develop some leadership skills, and to work with optimal productivity.

It is strongly advisable for the mentor to meet with undergraduate researchers either individually or in small groups on at least a semi-regular basis to discuss how their experiments are progressing and to observe the changing level of students' understanding of the research and related research articles. At group meetings the mentor should encourage all students to contribute to the conversation. When giving students specific directions for their next research experiments, the mentor should not take a student's understanding for granted but should make instructions absolutely clear by explicitly writing them out, rather than relying on students to remember details discussed only orally. This procedure not only tells the student exactly what to do next but serves as an invaluable reminder for the mentor. On occasion, after giving students such instructions, it is even appropriate then to ask them to describe orally their understanding of the discussion they have just had with the mentor. To keep everyone abreast of the scientific literature, a mentor can make each student responsible for reading articles (or at least their abstracts) in one or more journals pertinent to the mentor's research. At group meetings they can report on the articles they have found.

Safety guidelines. The mentor should discuss with students the established departmental guidelines for doing laboratory research, of which the safety guidelines are perhaps the most important. Safety guidelines should include the obvious procedures, such as wearing appropriate clothing and protective eyewear, banning food and drink in the laboratory, and barring unauthorized experiments. In addition, the guidelines should include such items as descriptions of proper disposal of chemical and biological waste, proper use of fume hoods, how to handle chemicals safely, and how to clean up a spill. Each laboratory-science department should have a stated policy regarding students working in the laboratory alone without direct supervision.

ENGINEERING

Mentoring undergraduates in engineering-research projects is very similar in many ways to performing this task in other academic disciplines, but there also are several differences, highlighted here.

First, undergraduate research projects in engineering tend to be applied and integrated (drawing upon knowledge across disciplines). This has important implications for the purpose and measures of performance of the scholarly work. Differences in purpose and measures of performance in the scholarship of integration and application require different types of knowledge, skills, and attitudes among undergraduates, compared with other types of scholarship. This, in turn, changes how one mentors undergraduate researchers in the engineering disciplines.

These differences are most evident, for example, in the design projects that often consume the majority of an undergraduate engineering student's scholarly activities (and a faculty member's mentoring work). These design projects are typically team-based application/integration projects that often involve external "customers," such as a company sponsor, and they focus on a "real world" problem that the students are attempting to solve on a timeline and a budget. Such projects often involve designing and building a prototype product or process as a "deliverable" at the end of the project. They often involve a formal technical report and presentation to the corporate sponsor (as opposed to a journal publication or conference presentation).

Thus, for example, undergraduates must learn to manage the expectations of the external customer throughout the timeline of the project, in addition to developing the technical knowledge and skills necessary to complete the project. This is particularly true in capstone design projects, which tend to be larger, more complex projects encompassing two, three, or even four semesters. This is often accomplished by using formal project-management techniques and software to manage the scope and deliverables of the project.

A second difference in mentoring undergraduate engineering scholars is the increased focus on laboratory and shop safety as a basic learning outcome. Since engineering students typically end up operating larger-scale process equipment and manufacturing tools in their projects, the level of safety concerns is often magnified, or at least different, compared with a traditional science laboratory. This added measure of professional performance also adds an additional level of responsibility to the mentor's role.

A final difference generally is the need for mentors of engineering student researchers to focus on professional-development skills such as formal report writing, interpersonal oral and written communication skills, management of customer expectations, project planning, and team management. These skills will be equally as necessary as technical knowledge and skills for completing an engineering design project.

On balance, mentoring undergraduate engineering scholars is similar to mentoring students in other physical-science or social science fields. The few differences outlined here arise mainly from the tendency of engineers to work on integration and application scholarship as opposed to other types of scholarship—and would apply to any discipline in which that type of scholarship is involved.

MATHEMATICAL SCIENCES

In the category of mathematical sciences, we refer to mathematics, computer science, statistics, and applied mathematics. Undergraduates doing research in mathematical

sciences, as in other scientific areas, do original work to investigate open questions. Although departments in these disciplines are generally classified as natural sciences, research in mathematical areas, both professionally and for undergraduates, differs greatly from research in experimental sciences. Most importantly, undergraduate researchers in mathematical sciences usually have their own projects, rather than working on aspects of a supervising professor's larger project. These individual projects raise special issues for faculty seeking to mentor undergraduate research. Other differences discussed here involve modeling and the role of data and examples.

One of the greatest challenges a faculty mentor in the mathematical sciences faces is devising a good individual project for a student or team of students. When a faculty member's own research has aspects accessible to undergraduates, it is often possible to find interesting open questions on which an undergraduate can make significant headway. However, many faculty research topics require so much technical background that undergraduates cannot reasonably work on worthwhile, open questions.

Occasionally an undergraduate course can lead to open questions. Many times, however, faculty members need to look for areas that interest them that have open questions that will be accessible to undergraduates. Faculty members seeking to start undergraduate research programs should talk to colleagues already handling such programs, as well as looking for relevant professional workshops. (For example, the Web site for the Math/CS Division of CUR has contacts for individuals looking for advice. The Mathematical Association of America often has workshops and mini-courses on relevant topics. See the Resources listed below.)

Because undergraduate research projects are generally separate from a faculty member's own research and require significant mentoring time, junior faculty interested in mentoring undergraduate research should find out explicitly how their department and institution regard such mentoring. Undergraduate research often doesn't lead to publications in refereed research journals, and even if it does, the mentor may not be a co-author. Some mathematical-sciences departments therefore count mentoring undergraduate research in a category other than the faculty member's own research.

Research in the mathematical sciences is often a solitary endeavor, which is reflected in the individual projects of undergraduate research. Since undergraduates might not be ready for such a regimen, mentors need to be proactive. They should establish good rapport with their students and check on them often, even more often than progress reporting might require.

Modeling provides an excellent way for students in the mathematical sciences to experience research and see connections with another area or discipline, such as biology. Whether the model is mathematical, statistical, or algorithmic, it provides a formal representation of some essential properties of a system of interest. Students can test the model and explore any parameters in order to provide a better understanding of the original system. Students can then improve the model in light of these tests. Also, students can investigate formal properties of the model that may provide new

insight into the system. These projects often are most effective when there are two mentors, one from the disciplinary area of the model and one from the mathematical sciences. In particular, this arrangement reduces the need for a faculty member to have expertise in two disciplines. As an additional benefit, the students learn to understand and communicate ideas in both disciplines.

Mentors need to be clear about the role of data, simulations, examples, counterexamples, general analysis, and proofs in the particular project a student is pursuing. In a project with the goal of producing proofs, examples are only initial stepping stones, although a student might not realize that distinction. In other projects, however, examples, simulations, and sensitivity analysis may be all that are reasonable to expect.

The mathematical community now provides many opportunities for student-research presentations, from regional conferences to the poster sessions at the winter joint mathematical meetings and the undergraduate sessions at Mathfest (the national summer meetings of the Mathematical Association of America).

Resources for further information include:

http://cur.networkats.com/members_online/members/divisions.asp?div=0005. This site lists councilors of the Math/CS Division of CUR who are willing to discuss ideas for research projects and other issues in mentoring undergraduate research.

http://www.maa.org/subpage_4.html. This site offers the main page for national Mathematical Association of America (MAA) meetings, which links to information about workshops and mini-courses, as well as opportunities for student presentations.

http://www.maa.org/columns/resources/resources_2_08.html. This site and its links provide information on undergraduate research in mathematics.

FINE ARTS

Although undergraduate research traditions and methods in the fine arts are not established, faculty in the fine arts do have traditions of engaged learning that can be easily modified and rebranded as undergraduate research and creative activity. These traditions of engaged learning can have direct and significant benefits for students. For the purposes of this discussion, the fine arts have to be divided somewhat, as the activities vary greatly, from musicological research that follows the guidelines in the history or humanities sections of this manual, to creative activities in performance, where the activities differ substantially. In between the ends of that spectrum are studies involving surveys of artists; interdisciplinary arts research and creativity; discoveries of new artistic methods; studies in aesthetics and artistic perception; and many other topics. In fact, if it is true discovery of knowledge, there should be many approaches that nobody has yet imagined.

Exploring the connections among fine arts disciplines is something that excites many fine arts faculty members, while offering them an avenue of discovery to explore with their undergraduates. The aesthetics of art and music often inspire architects,

for example, and the extent to which music is a vital element of film is fascinating. Bringing students together to help tease out these links can lead to productive interdisciplinary seminars and has potential for much more discovery and many more publications and original works of art (*CUR Quarterly*, Winter 2008, Young).

Whether students creating an original work of art, performing a musical composition in a unique and creative way, or otherwise doing what fine arts faculty do as part of their research actually constitutes undergraduate research raises interesting questions that are not easily answered. Thanks to very smart computer-notation programs, for example, a student who knows little about music can "compose" a symphony by entering random notes on a computer and pressing the "arrange for orchestra" button, and then print a full score and impressive-looking set of parts. So the faculty mentor not only must evaluate the final student project, but also must guide the work to ensure that the learning process is genuine, that the student fully understands how seasoned composers work, and learns the techniques involved in bringing an idea to the fore as an authentic work of art. Selecting the right students, of course, is important.

Ideally, a synergistic relationship is created between mentor and student, just as in the science-lab model, where professors truly benefit from the help of their undergraduate researchers, and vice versa. In fact, in the sciences, a ladder approach is sometimes used in which senior undergraduates are mentored in part by graduate students, and those seniors in turn mentor freshmen and sophomores, which saves the faculty member some time. Some faculty in the fine arts have adopted a similar model with great results, but others find that their students lack the skills needed to assist in any significant way. One approach for faculty is to ask the following questions:

- What aspects of my creative work could I use some help with, in exchange for engaging a student in the process for his or her benefit?
- Are there interdisciplinary questions I might explore with students and perhaps with a faculty member from another discipline?
- Could a group of students work with me, foster each other's thinking, and come up with a product that is at least tangential to my work?
- Is there a completely new avenue of scholarship that might reinvigorate my own creativity that students could help me develop?
- Are there ways of looking at my own discipline, perhaps through the lens of another discipline, that have not been fully explored in the literature?
- Is there a particularly talented student or two who could take on a project, perhaps related to my work, with minimal supervision?
- Could I teach a small seminar on creativity and work with the students to come up with ideas for projects that none of us has thought about?

Given the inherent creative nature of faculty in the fine arts, and our passion for our art form, it seems reasonable to be optimistic about the many ways we could imagine, invent, discover, and explore in order to successfully mentor undergraduates' research/creativity in the fine arts.

Although undergraduate research—and initiatives to encourage undergraduate research—are becoming more and more popular not only at primarily undergraduate institutions but also at large universities, many students, faculty, and administrators still associate the term "research" chiefly with the sciences, which do offer rich opportunities for collaborative efforts and mentorship. And while many faculty in engineering, chemistry, or psychology, say, can trace at least a bit of their passion for research to their own early experiences in a "Research Experiences for Undergraduates" program, in the humanities this approach is unfamiliar and there is no real culture of collaborative undergraduate research upon which either professors or students can draw.

One of the reasons humanities faculty are often reluctant to take on an undergraduate research apprentice to assist them in faculty research is the complexity of skills required in order to conduct substantive research at a professional level. The lack of a collaborative culture does not, however, mean that humanities undergraduates do not conduct research. Rather, such research tends to take place as part of coursework. Research and analysis papers are common assignments in upper-level courses, even at large institutions, and humanities curricula often culminate in a senior thesis or capstone project for majors. Below we will address strategies for successful mentoring in the classroom setting. (Please also see the Historical Research in the Social Sciences section.)

Essential skills for humanities researchers. Beyond critical-thinking abilities, in order to conduct successfully research in humanities disciplines such as literary studies or art history, students need to develop a constellation of skills, including:

- training in formal analysis (for example, of a poem or passage, a painting, a musical composition);
- an understanding of the tradition of the creation of relevant works, including the role of (and the ability to recognize) allusion and imitation, specific iconography of the period or tradition in question, and Biblical, classical, or other relevant references;
- the ability to identify and analyze appropriate secondary literature, and to understand, and draw upon the implications of, such materials' arguments; and
- the ability to synthesize, analyze, and draw upon the above, to adduce evidence to support and defend the student's own argument or thesis.

In addition to content areas, a solid grounding in library-research skills is essential for anyone seeking to conduct research in humanities disciplines; ideally, thesis students, potential humanities researchers, or any humanities major should receive training in finding primary and secondary sources in books and journals, online and in print. They should be taught how to evaluate such sources (for example, what is meant by "peer review," the significance of university or commercial presses, the credentials of the author), how to properly cite them, and how to use interlibrary loan and other resources to expand the material accessed. Rather than having each mentor teach these skills to each

student, they can easily be included in existing courses or a one-credit course in research methods taught by a skilled research librarian. Students often do not know that their college or university librarians are available and, indeed, eager to help interested students.

While all of the above elements need to work in tandem for students to create their own independent research projects, each element can be taught in a classroom setting; ideally the curricula for humanities disciplines should include training in each of these areas. And properly trained students, in addition to having the skills to write papers of their own, thus should be equipped to provide assistance to a faculty mentor.

Teaching the skills. In teaching the skills outlined above either to individual students or to classes, it is often most effective for the mentor to design assignments that focus on specific skills, rather than assigning a short paper that incorporates several at once.

Below is an example of skills-based assignments surrounding Botticelli's *Birth of Venus* that can be used with individual students, as part of a regularly scheduled class, or in a research-focused class:

- Write a two- or three-page close analysis of the image itself. The student should be advised NOT to draw upon any secondary sources (including Internet sources) beyond a copy of the image itself. Although it is also effective to have students present their analyses orally, frequent writing practice is important in training the student to conduct substantive humanities research.
- Identify two to three primary sources relevant to an understanding of the painting—for example, the description of the birth of Venus from Ovid's *Metamorphoses*; the 3rd century sculpture known as the "Medici Venus;" and the description of the birth of Venus found in Poliziano's *Stanzas*, a poem contemporary with Botticelli's painting written by a poet who travelled in the same intellectual circles as the painter. Write a paragraph about each work and why it is relevant to understanding Botticelli's painting; identify three secondary sources that could help you learn more about this work.
- Find five recent articles about Botticelli's painting.

To train students to evaluate secondary works, it is often helpful for the mentor to identify at least two well-written articles with somewhat opposing viewpoints.

SOCIAL SCIENCES

The term "social sciences" acts as an umbrella for an extraordinarily broad and diverse range of intellectual activities. This section will not attempt to explore the full breadth of activities encompassed by the label "social sciences," but rather will discuss various structures that can be built to encourage undergraduate research in the social sciences and deal with the important issue of research ethics. Because historical research presents unique challenges, a final subsection specifically discusses undergraduate research in this discipline.

Building structures for mentoring. At most institutions, the emphasis is on courses, including objectives and content. Whatever our academic discipline, faculty members have an idea of what majors should be learning in their classes. This is not to say that there is always a clear consensus, without debate; rather, the point is that the end result of years of study is a fairly clear picture of what the major should include.

Even so, it is often how we go about conveying our knowledge and understanding to our students that makes all the difference. Within the academy, many colleges and universities have created structures that encourage and support students in the process of acquiring knowledge and experience, thereby offering opportunities that challenge and excite the intellect of students as well as their faculty mentors. Because we, as faculty members and mentors, want to create programs and processes that work for our students, we have included here three examples of structures designed to bring faculty mentors together with students in ways that are enriching to both, although in different ways.

Research as enrichment of the entire undergraduate experience. In the Honors College at the University of North Texas, faculty members recognized the importance of research for their undergraduates and set about creating a research track within the college. The result was an interdisciplinary program that integrates research done with a faculty mentor into all four years of the typical undergraduate's education. The research track turns out confident students who are accomplished researchers, ready to take on the joys and rigors of graduate study. While providing close mentoring to a relatively small number of students among the 36,500 who attend the university, the Honors College has contributed to the undergraduate experience for all students by demonstrating leadership in structuring opportunities for undergraduate research.

Components of the research track cover all aspects of research, beginning with identification of research interests in a seminar-style class for first-year students. Students are encouraged to identify and narrow their areas of interest and find a faculty mentor who promotes early involvement in research projects. Higher-level classes work toward the development of a thesis proposal, thereby laying the foundation for the actual thesis project. All students who write a thesis are offered opportunities to present their work in poster or paper form, often at disciplinary conferences with their faculty mentor. An annual University Scholars Day recognizes and celebrates undergraduate research and the faculty members whose mentoring makes such opportunities possible. Students may then submit their papers for publication in *The Eagle Feather*, an online journal of undergraduate research developed and edited by faculty members of the Honors College and students under their supervision.

One unfortunate truth is that many students come to college without having developed a good understanding of academic integrity, including plagiarism and the need to cite the sources of ideas, as well as the sources of direct quotes. Even those who understand the need to cite sources carefully do not grasp that there are several standard systems of citation. We recommend using one of the major systems—those

of the American Psychological Association, the Modern Language Association, or *The Chicago Manual of Style*—and train students to use the system in all their written work so that its use becomes second nature.

Students engaged in research for the undergraduate thesis are expected to adhere to the same ethical standards and to comply with the same research guidelines as more senior researchers. The university's director of Research Compliance meets with the freshman-seminar students to discuss academic integrity, ethical treatment of human and animal subjects, and conflicts of interest, and explains how to avoid violations in their research. The students also watch and discuss *Susceptible to Kindness* (1993), a documentary film based on interviews with some of the men who survived the Tuskegee syphilis-experiment research.

The research track is designed to be a partnership among Honors College students and faculty as well as faculty mentors in the students' home departments. While the Honors College courses are designed to foster early interest in research, the completion of a successful thesis ultimately depends on developing a successful collaboration with a faculty mentor in the student's major.

Honors College faculty and mentors have found that presenting completed research projects in oral and written forms is addictive for undergraduates. Once they have experienced the sweet adrenaline rush of the spotlight, many undergraduates are eager for more. And we know these students are the ones who go on to the most prestigious graduate and professional programs and are the most likely to have research fellowships to prepare them for their eventual careers.

Helping students see themselves as scholars: The role of a writing course. Undergraduates too often think of themselves as consumers—of knowledge, of educational services, of career training. A great benefit of expecting students to engage in scholarship is that they shift from a passive approach to learning to an active role that involves taking responsibility for their learning. And one of the ways to encourage this is for faculty mentors to engage students in the same work they themselves are doing, modeling what scholarship looks like through joint efforts on the same projects.

At Duke University, all first-year students are required to take a course called Writing 20: Academic Writing. Taught by post-doctoral teaching fellows from dozens of different disciplinary backgrounds, most courses introduce students to both topical material and to academic writing by having them take on serious independent research. For instance, one faculty member led a course called Ghosts on the Landscape: The Abandoned Buildings of Durham, in which students came to understand modernity and cultural patterns of (dis)investment through the close examination of abandoned commercial buildings near the Duke campus in Durham, North Carolina.

In addition to their field research, students read major theoretical work concerning modernity and urbanism. Rather than a textbook with pre-packaged interpretations (which strive to seem "neutral"), students engaged with lively, opinionated original texts. Marshal Berman's *All That Is Solid Melts Into Air* was the "master text,"

complemented with articles and chapters from major journals and edited collections. Each student also was assigned an additional book that focused specifically on his or her emerging research interests and was required to write and present an interpretation of that book.

The course was guided by its instructor, but students also were introduced to the university library's local-history collection and its staff, as well as to the director of education for the local historic-preservation society. The relevant librarians and the society's education director led one or more sessions of the class, not merely so that they could deliver content, but also so that students could understand something of scholarly collaboration. Those partners also generously made themselves available for telephone and e-mail consultation with individual students to answer questions about methodological and interpretive concerns.

Those kinds of intellectual adventures can mark the transition in students' lives from being readers to being thinkers, from consumers to producers, from students to scholars. And it was important that the instructor had not had prior history with the buildings being studied. He helped students create interpretive frameworks for what they were seeing, but he was equally a learner of the details of Durham's urban history (having only lived in the city for eight months when the course began). So when questions arose, he was able to model the skills and attitudes of an engaged scholar, uncertain about emerging factual details but capable of finding those facts, and more importantly, linking newfound facts to interpretive and argumentative frameworks. It is crucial to contrast this kind of work with the sort of imitative research that students so often encounter, in which students deal with something new to them but well-studied by others. In this case, these first-year students were truly doing research that no one else had previously done, and in which there was strong community interest.

Combining undergraduate research with other high-impact pedagogies, such as study abroad. As in the example above, good undergraduate research is often difficult to distinguish from community service or travel programs. Travel abroad and service learning provide unique opportunities for undergraduate research. Students can immerse themselves in a different culture and engage at a new level with the communities of which they are a part. At the same time, however, supervising and mentoring students who are conducting research abroad or in the local community can also provide distinctive challenges for both faculty and students.

At least three key factors are involved for faculty members in making this type of undergraduate research successful: selection of students, preparation, and flexibility/adaptability. All are related to the "key traits of mentorship" noted in Part I.

First, selection of students requires a degree of faculty "forwardness." Not all students have the skills, maturity, or drive to engage in research while away from the direct supervision of a faculty member. Also, because research abroad requires a great deal of preparation, faculty members should constantly watch for students with the potential to be successful, because it is beneficial to identify them early in their academic careers.

Second, faculty mentors/supervisors must take special care to prepare students for their work. In cases in which students have not yet taken a research-methods course, faculty members prepare special readings and provide individualized instruction that will give students sufficient background to be able to conduct their research. In the context of study abroad, before students leave for their host institution and city, students meet with departmental faculty and are assigned a primary thesis advisor, who then serves as their main point of contact on the home campus while they are away.

Finally, and perhaps most importantly, faculty flexibility and adaptability are essential. Both are related to the earlier discussions of persistence and emotional honesty. Research abroad can pose unique challenges, and students should be prepared for the struggles they may face. Students need to be aware that challenges and obstacles are likely to be part of the research process. Faculty members should share their own experiences in this regard, helping students understand that, while research is rewarding, it can also be frustrating and tedious. Connecting future thesis writers with students who have already conducted their thesis research abroad is also beneficial, because hearing the perspectives of others like themselves can help to ease some of their anxieties.

The same issues arise when faculty mentors present opportunities for service learning. Just as with studying abroad, the students engaged in a service-learning project must be identified, prepared for their work, and ready to deal with the unexpected. The faculty mentor is key to promoting flexibility and adaptability, because, as we all know, situations change and challenges erupt. Faculty mentors are also key to matching students with organizations and projects that will engage the particular students and with providing adequate preparation and guidance to make the interactions successful. It is hard to imagine study abroad and service-learning projects proving successful in the absence of effective faculty mentors.

Research ethics. A discussion of mentoring for social science students would not be complete without dealing with ethics. Once again, the faculty mentor is key in this area, since social science research often requires the use of human subjects, and thus it is crucial that students understand some of the ethical issues involved in human-subjects research. Any research that is "designed to develop or contribute to generalizable knowledge" is subject to approval by an institutional review board (Office for Human Research Protections, Code of Federal Regulations, Title 45, Part 46). This includes, for example, undergraduate research that is to be published or publicly presented beyond the confines of the student's institution (including presentations or posters at student conferences such as NCUR, the National Conferences on Undergraduate Research). Because this is a new issue to students, faculty mentors must make certain their students understand the need for such regulations and the negative implications of moving ahead with research without securing appropriate review-board approval.

While course projects have traditionally been exempt from formal IRB approval, this is increasingly not the case. Some colleges and universities require instructors of research-methods courses to file a course-wide waiver that binds all of the student projects to certain standards (typically non-publication; no sensitive topics; no vulnerable populations; no connection between data and identifiable participants or participant groups). In addition, many colleges require methods instructors to pass college-based or externally based ethics training, and to teach ethical practices as part of their methods courses. Some colleges require that the students themselves go through college-sponsored ethics training, as part of their education, even if they are not doing research themselves. Faculty mentors must make sure that students know they cannot conduct research in any of the social science disciplines without a clear understanding of the rules and regulations governing their work.

Before undergraduates have actual contact with human subjects in a research project they are required to become certified to be involved in research involving human subjects. This training usually involves reading a tutorial and passing a test that includes questions concerning the history of institutional review boards and the governmental rules and regulations regarding the conduct of research involving human subjects. The particular tutorial/test that any particular institution requires is, to some extent, up to the institution, but most of them cover the same basic history and regulations.

While these tutorials touch on the basic ethical information students must know before having contact with human subjects, students should, in addition, receive more in-depth training on the topics covered in the tutorial. These topics are often covered in more depth in research-methods courses in many disciplines that frequently use human subjects, such as psychology. In-depth information on these topics is therefore readily available in many basic research textbooks. The topics generally include the idea of weighing risks and benefits of the research, deception, coercion, and research using special populations (e.g., children, institutionalized people, or people with cognitive disabilities). Most of these issues are more complicated than they might appear. Therefore students should receive some additional training in these matters beyond reading about them in a tutorial or textbook. Important topics include:

- **Risk/benefit analysis.** Students should understand that any research involving human subjects should try to minimize any risk to the subjects and maximize any benefits of the research. Risks include physical risk, which is frequently a concern with medical research but rarely a concern with social science or educational research. The risks that are more commonly a concern for undergraduates doing social science research are those "that could reasonably place the participants at risk of criminal or civil liability or be damaging to their employability, insurability, reputation, or be stigmatizing." These risks include disclosure by the subjects of their involvement in illegal activities; release of mental or physical health information; genetic information; or disclosure of sexual orientation or religious beliefs. Before any research is conducted, the risk to the subject must be weighed

against the benefits of the research to the subject and to society. This weighing is the job of the IRB (institutional review board), but students should understand the factors that enter into such an evaluation.

- **Informed consent and deception.** Students should understand the concept of informed consent and that any human subject has to understand the purpose of the research in which he or she will participate. Subjects must also understand exactly what will be required of them as subjects, any risks to them if they participate, and any benefits to themselves and others. This information should be contained on a consent form that the participant reads and signs prior to participation in the study. Student researchers should understand the research in which they are involved so that if subjects ask any questions about the study, the students are able to answer the questions. In addition, the consent form should include contact information so that if the subjects have any additional questions concerning the study after they have signed the consent form, they can contact someone (usually the principal investigator) who will be able to answer their questions.

  Students should understand that occasionally deception is involved in a study or some information about the study is omitted from the consent form. In that case, students should understand the need for deception or incomplete disclosure. In some types of research, deception is necessary in order to obtain valid data. In those cases, if the deception does not result in great risk to the subject, it may be better to deceive the subject in order to maximize the benefit of the research because data that are not valid are not beneficial. Student researchers should also be educated concerning debriefing of subjects who have been part of studies involving deception or incomplete disclosure. Only after subjects have been told the exact nature and purpose of the study can they give *informed* consent, and students must understand that only after subjects understand the study can they give their consent for their data to be used by the researcher.

  Assent. Certain groups, such as people under the age of 18 and those with cognitive disabilities, cannot give informed consent. Consent must be given by a parent or guardian and then assent must be obtained from the subject. Although a parent or guardian might give consent, indicating that the subject may participate in the study, it is still up to the subject to agree to participate by giving assent. Assent is similar to informed consent in that the subjects are informed to the greatest extent possible what will happen to them in the study and why it is being done. It has to be made clear to them that they don't have to participate and can stop participating at any time. So although these individuals are not capable of giving legal consent, they still have to understand to the fullest extent possible that they do not have to participate in the study if they do not want to do so.
- **Coercion.** Coercion involves any undue pressure placed on subjects to participate in research. At universities, much research involves student participants who are participating as research subjects as a requirement for a course. The use of "subject pools" can reduce the pressures because they allow student-participants to fulfill their course requirement by doing some task other than participating in research,

thus avoiding coercion. Other studies pay subjects for their participation, although the amount of compensation cannot be so large as to be coercive. Students also must be aware that even if it is not intended, coercion can occur when subjects perceive that they will either be rewarded for participating or punished for not participating as, for example, when the researcher has academic authority over the subjects. This might be the case when teachers ask their students to participate in a study or when inmates are asked to participate. Student researchers should participate in discussions about what degree of coercion is acceptable given the benefit of the study.

- **Respect.** Student researchers need to understand that they should treat with respect the people participating in research. The subjects are doing the researcher a favor by participating and without them the research could not be done. For instance, the researchers should always meet the subjects at the appointed time and not keep them waiting. Also, researchers should make subjects as comfortable as possible while they are participating. Further, researchers should thank the subjects for their participation when they arrive and when they leave.

The best place to get information on the topic of the ethical conduct of research is the Web site of the US Department of Health and Human Services Office of Human Research Protection (OHRP): http://www.hhs.gov/ohrp/policy/index.html#topics. Particularly useful are the Frequently Asked Questions and the Human Subject Regulations Decision Charts. The Spring 2010 issue of the CUR Quarterly has several relevant articles. CUR has recently begun a Research Ethics Initiative, which will compile best practices for ethics and responsible-conduct reviews related to student research. The project is envisioned as a two-year initiative, which will result in publications and possible recommendations for college administrators, IRB members, and professional societies. We hope that this work will help to clarify the sometimes-uncertain processes for review of student research.

Historical research. Historical research presents undergraduates with a unique opportunity to encounter firsthand the types of artifacts and materials historians use when they reconstruct the past. For many undergraduates, the process of working with these primary source materials, interpreting the materials in the context of previous historical perspectives, and then developing a narrative that can inform wide audiences about the relevancy of their topic brings great, often unexpected, satisfaction. The experience might even spur a student's ambition to attend graduate school and train to become a professional historian.

Undergraduates can engage in historical research to some degree through classroom assignments, but projects outside of the classroom provide opportunities for deeper research. One option is for a student or a small group of students to engage in ancillary research on a project being conducted by the mentor or to engage in collaborative projects. It helps considerably if a faculty member's institution

encourages undergraduate research through use of a collaborative-research grant, particularly if the support is provided over the course of a summer.

Over all, students interested in conducting historical research ought to be encouraged to "think big" and shoot for something few students imagine doing at this stage in their lives: publishing an article. Campus student-research journals and state historical publications are both ideally suited to polished student articles. Research conferences and university-sponsored symposia, as well as other opportunities such as the Council on Undergraduate Research's "Posters on the Hill," event afford students additional opportunities to share their insights and showcase their talents.

While encouraging students to "think big" in terms of outcomes, it is often a good idea to temper a student's ambition for the scope of research. Historical research is a very time-consuming enterprise that requires intensive archival detective work, as well as a comprehensive knowledge of the secondary literature informing a given topic. Furthermore, since many students do not have the time or financial resources to conduct research far from home or campus—although academic institutions are increasingly providing students with some research funding—students might be steered toward an archival collection within easy reach. Familiarizing students with the nearly limitless possibilities for historical research that exist within all regions will allow nearly any student interested in United States history to focus on a subject of interest. For example, an undergraduate interested in investigating the history of the polio epidemic in the United States need not re-write David Oshinsky's magisterial treatment of the subject, but instead might test several of his insights on the local level—plumbing newspaper accounts, digging through local government records, researching wide-ranging materials at local archives, and pursuing oral-history interviews with people in the local community who survived the epidemic. (Students interested in conducting oral histories, however, will undoubtedly require guidance on developing skills as interviewers and on following relevant procedures set out by the campus's institutional review board. Further information can be found at many university oral history centers and at http://www.oralhistory.org/)

Since most undergraduates are unfamiliar with the protocols and procedures governing archival research, it is a good idea to acquaint students with a particular archive before or during their first visit. Have the students develop an intuitive, adaptable method of recording historical evidence—a database spreadsheet, for example, with separate fields for every component of data that will be kept for future use (author name, titles, publication information, archive location, etc.) Such careful recording will pay dividends when the student begins to write. Undergraduates often need to be taught about the ever-expanding resources available online through institutional resources such as ProQuest Historical Newspapers. Walking students through literature searches on comprehensive bibliographical databases of the Online Computer Library Center (OCLC) (which often lead to requests for materials through interlibrary loans) will encourage them to seek out and later incorporate the most up-to-date and relevant secondary source material.

As students delve into the historical evidence available to them through the sources mentioned above, as well as many others, their interest and enthusiasm for their projects are likely to grow as unanswered questions multiply and the unresolved mysteries of the past begin to beg for further attention. At some point, usually after several months of research into primary and secondary sources, students must commit to the arduous process of writing, where interpretation unfolds gradually through numerous rounds of editing and occasional forays into follow-up research. Students are often unprepared for the duration of this stage of their work (which could take four to six weeks and perhaps much longer to develop a good article-length study), so faculty mentors serve their students well by requiring them to stick to set timelines.

Because historical research is very time-consuming, proceeds without a clear blueprint or definable set of boundaries, and the task of translating historical evidence into clear, concise narrative prose is very demanding, undergraduates who commit to creating their own historical interpretations will be considerably challenged. In the end, however, they will be able to take great pride in the results of their historical research and understand the joys of engaging the past for the benefit of others.

Part III. Other Important Considerations

INTERDISCIPLINARY RESEARCH

Research that crosses disciplinary boundaries is being encouraged by industry, the medical fields, government, and scholars. Supporting the need for such research is the emergence of problems that cannot be addressed using one disciplinary approach, as well as the increased demand for cross-cultural understanding in the global community. Biochemistry as a "discipline" resulted from years of collaborations between biologists and chemists; neuroscience is a relatively newer interface between biology and psychology. The current push to expose students to research that requires multiple areas of expertise seems to derive less from the development of new interdisciplinary fields and more from the increased recognition of the value of using experts in different disciplines to study a problem. For example, environmental scientists, physicists, engineers, sociologists, and anthropologists or historians all might be essential to a restoration project in a community. In fact, "community-based" research is by its nature an interdisciplinary enterprise.

Biology and mathematics connections have grown and more support is available, resulting, at least in part, from the mandate in Bio 2010: Transforming Undergraduate Education for Future Research Biologists[1]" to improve quantitative skills in students training for biomedical careers. The NSF Undergraduate Biology and Mathematics (UBM) fund is supporting both curricular and research projects nationwide. The UBM-supported research projects are encouraged to have faculty members from both disciplines working closely together, so that the undergraduate participants actually begin to master some of the skills in the areas where they lack training.

Mentoring in a truly interdisciplinary research arena presents special opportunities and challenges for faculty members. An essential ingredient in such a setting is fearlessness. One must be willing to take risks beyond the usual, "I don't know, but I can find out" response to questions, because often it is quite difficult to simply "find out" something beyond one's area of training. The opportunities presented by interdisciplinary research are also great: modeling of lifelong learning by the mentors who are themselves ready and eager to learn. Working together and learning as a team of students and faculty from different disciplines can be extremely exciting and rewarding. Students in these situations often feel more empowered, because they are generally better prepared than the faculty member in the discipline "opposite" from their own and can feel satisfaction in quickly becoming teachers themselves.

Interdisciplinary research is receiving more attention from government agencies, industry, and foundations, for the reasons outlined. Therefore, funding opportunities may increase over the next few years, encouraging courageous faculty members willing to think broadly and push the parameters of their disciplines to move in this direction.

---

[1] Bio 2010. **National Research Council. Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century.** 2003. National Academies Press, Washington, D.C.

Most of the advice in this volume addresses faculty members who oversee research projects undertaken by undergraduates on topics closely related to the faculty members' expertise. When these mentor-mentee relationships exist in the context of a university offering graduate programs in disciplines in which undergraduates engage in research with faculty, the resulting research groups often involve both graduate and undergraduate students. In these cases, graduate students may take on all or part of the role of mentoring undergraduate researchers, sometimes with explicit direction from the faculty adviser, but often on a more informal level.

Graduate students can make very effective mentors of undergraduates, since they can often relate well to the undergraduate experience and provide important advice on their mentee's next steps in school and beyond. In addition, graduate-student mentors can benefit from learning how to teach and coach their mentees to become productive researchers. However, because the mentoring role for graduate students is not always as explicit as the faculty's mentoring role, graduate students may find themselves in situations for which they are not fully prepared. In this section, we will address some of the concerns that arise and suggest a framework for ensuring that both graduate and undergraduate students benefit from these critical mentor-mentee relationships.

Complexities of the graduate student's role as mentor. There are three major areas in which the mentoring relationship becomes especially complex and requires special consideration. The complexities involve communication among all team members and between each pair of team members; the need for preparation and training so graduate students can effectively supervise and mentor undergraduates; and timing of the research project with respect to the graduate student's own educational milestones.

As in all relationships, communication is key. When a graduate student serves as a secondary, but often a more day-to-day mentor of an undergraduate researcher than does the faculty mentor, communication is more complex because of the three-way nature of the relationship. For this relationship to be successful, it is important that the faculty member, undergraduate, and graduate student all share common understandings of the expectations and roles of each member of the team. Since a large portion of the direct communication will be between only two members of the team (undergraduate-graduate student, graduate student-faculty adviser, undergraduate-faculty adviser), there is ample opportunity for misunderstanding and miscommunication to arise.

Planning and training are also critical. The more advance notice a prospective graduate mentor has about potential mentees, the better he or she can prepare and acquire any training or resources needed to plan for the new role. A graduate student may not ever have supervised the work of another person, and often will have little training in mentoring techniques. Finally, graduate students are also subject to greater pressure at certain times during their education, particularly when they are preparing for exams or writing theses.

The following framework has been found to help tremendously in fostering successful mentoring in research projects involving faculty members and both graduate and undergraduate students:

- **Begin the project with a written plan, including research goals, starting points, and expectations of each mentor and the mentee.** Ideally, the graduate student will be involved in the selection of the undergraduate researcher, and the graduate mentor's role in the initial training and integration of the undergraduate student into the research project will be explicit. It can work well for the undergraduate student to be responsible for writing the project plan, with input and approval from both mentors. Be sure to have the undergraduate and graduate student add their own personal learning goals; this can help make explicit what these students hope to gain from their association with each other and with the research beyond the actual research results. When the research has taken an unexpected turn, seems to be stalled, or returns negative results, returning to a discussion of these personal learning goals can help keep students motivated. Having some key written documents agreed to by all three parties can really help to ensure shared understanding, both at the beginning of the project and as the research proceeds and evolves.
- **Create a schedule of regular meetings and milestones.** Reserve a regular time to meet as a whole group and also individually to discuss the project and students' goals and milestones. Return often to the timeline to modify expected milestones as research progresses and approaches may change. Make these changes in writing when possible and be sure all parties are informed. Be sure to convey a realistic sense of when to expect significant research results, but also be sure to make note of smaller steps and recognize the gradual acquisition of skills and learning by both graduate mentors and undergraduates.
- **Provide relevant resources or training for graduate mentors.** The most common problems seem to arise from graduate students' lack of experience and training in supervising and mentoring others. Faculty can take this opportunity to review literature on mentoring together with the graduate student, and help the graduate student think through situations that arise with their mentees. Sometimes a group of graduate students who serve as mentors can meet with an experienced faculty member to discuss common issues and solutions. Some departments even offer a seminar for graduate students to learn explicitly about mentoring; this topic could also be woven into a departmental teaching-methods course.
- **Address responsible conduct of research, including publication authorship and ownership of data, before any problems arise.** Authorship can be more complicated with a larger team of people involved in a project. The best way to avoid problems is to talk openly about how any results will be published at the beginning of the project. Include a discussion of responsible conduct of research for advisees at all levels, either in the small group or as a departmental seminar or workshop.

- **Factor in the graduate student's major educational milestones when inviting undergraduates into a research project.** Even a graduate student who has been an outstanding mentor for undergraduates can have an unsuccessful mentoring experience when she is preparing for final exams or for a thesis defense. Similarly, a graduate student just starting her own program may not be able to provide the attention an undergraduate researcher may need. Graduate students may be reluctant to admit to their faculty advisers that they cannot serve as a mentor during a particular semester. The best advice is to avoid assigning mentoring duties during a graduate student's first semester or during critical exam periods.
- **Recognize achievements in research, as well as in mentoring.** Be explicit about noting undergraduate and graduate students' accomplishments, and help them find ways to present or publish their work. Be explicit, too, about the advances your graduate student is making in developing skills as a mentor. Find ways to recognize the graduate student's impact on mentees and the skills acquired that will be useful in an academic or other future professional position.

Benefits of a scaffolded mentoring model. Graduate students can serve as outstanding mentors to undergraduates, and learning to introduce students to research is an essential part of preparing for an academic career. The nature of the graduate mentor-undergraduate mentee relationship, however, is very different from the relationship graduate students have with their faculty adviser. Undergraduates with graduate-student mentors gain insight about graduate school and how to take the beginning steps of entering into a profession. Although there are some extra supervisory steps involved, the time gained by faculty members who can rely on a graduate student to provide a lot of the one-on-one instruction undergraduates need in basic research methods can be an important factor in a faculty member's ability to maintain an active research program. Over all, undergraduates who have successful mentoring experiences with both faculty and graduate students get the best of both worlds.

LETTERS OF RECOMMENDATION

One of the most consequential jobs of the research mentor is writing letters of recommendation. Graduate schools, other research programs, and potential employers are counting on mentors to give them an accurate description of the student's critical-thinking ability, speaking, writing, and other skills, such as laboratory skills and ability to work individually and in a team. While writing letters can be time-consuming, a mentor's evaluation is critical because the mentor's opinions and comments will be very important to the student's future. Be prepared for the requests for recommendation letters in the fall for graduate and professional schools and in January for summer-research programs.

Faculty members at R1 institutions who review graduate applications offer the following suggestions to colleagues who write letters of recommendation for graduate programs. They can be adapted for letters of recommendation for jobs and other opportunities.

- Give specific details about why this student is special and why he/she would make a successful graduate student. Emphasize the student's positive characteristics and the experiences he/she has had.
- Compare the student with other students in his/her class.
- Compare the student with other students you know who have gone on to graduate school in general and with students who have gone on to this specific graduate program.
- Describe the student's passion for the field of study.
- Talk about the student's academic achievement, but go beyond the discussion of grades to talk about talents, skills, abilities, and achievements that provide indicators of success in graduate school.
- If a student has asked you to write a letter of recommendation, and you do not believe the student would be match for the institution or program, it is critical to discuss it with the student prior to writing the letter. If the student still wants you to write the letter, it is important to communicate your opinion in your letter.
- If you do not strongly support a student, but the student still wishes you to write for him/her, lukewarm support may come across in a brief letter where what is NOT said can be as important as what is said about a student

PREPARATION FOR GRADUATE-SCHOOL APPLICATIONS

Mentors of undergraduate researchers are uniquely positioned to offer sage advice to their students concerning the decision-making and application process for graduate school. If a student is capable of graduate study, the mentor should encourage the student to consider pursuing a post-baccalaureate degree. The mentor should encourage the student to seize opportunities to expand on the current undergraduate research by delving as deeply as possible into the problem. The student might also be encouraged to seek opportunities for more undergraduate research at other institutions, if there is time.

Mentors should specifically:

- Talk with the student about what he or she enjoys (or doesn't) about doing research, provide observations about what he or she does well, and communicate the reasons you think the student would do well in graduate school. Such discussions can help a student develop the insight necessary to decide whether to apply to graduate school.
- Tell the student what graduate school is like, how it is different from undergraduate education, and be candid about the rigors of a graduate program.

- Convey that the best reason for pursuing a graduate degree is the student's personal interest in and passion for the field. Just because a student has achieved academic excellence does not necessarily mean he or she will want to do research or will be good at it. It also does not predict the student's personal capacity to cope with the rigor of graduate school.
- Discuss the many resources a student can access when considering graduate school. Mentors often know about various graduate programs in their fields. Students should be encouraged to contact other faculty knowledgeable about programs and institutions the students are considering. Alumni are also good sources of information. Visits to potential graduate programs provide valuable information about the atmosphere and support that may be hard for students to obtain otherwise.

As students start the application process, mentors should give specific advice.

- Research mentors offer the best insight into a student's talent and abilities. Mentors should be prepared to write letters of recommendation for their students. Often students need suggestions about others to ask for letters of recommendation to ensure that the writers' knowledge of the student will be pertinent to the reader.
- In their personal essays, students should focus on their experience and interest and less on their motivation for graduate study.
- Student essays should indicate that they have given some thought to why a specific graduate program is of interest to them.
- Personal statements should be specific to the institution the student is applying to and should not be a general statement used for all applications.

Conclusion

As faculty members, we teach, we supervise, and we mentor. While each of these activities is rewarding in its own way, most members of the academy rejoice at the opportunity to work one-on-one with talented and motivated students. We view such work as more than a mere project, but rather as important to the development of the student toward a life of learning. In this publication, we have attempted to offer guidelines for those who would be mentors, suggesting the need to identify good students and encourage them to learn how to do scholarly work.

We have provided examples of innovative approaches to mentoring in a wide variety of disciplines to illustrate the key idea that mentoring can—and should—take many different forms in order to be useful to students. Everyone would agree that mentoring at its finest allows an established scholar to work with a budding scholar to inculcate the foundational views of what it means to learn what others have discovered and train to contribute eventually to the body of knowledge in our discipline. We would also agree that while mentoring can be challenging and demanding for those who would do it well, it is also gratifying and meaningful work.

Appendix A: Frequently Asked Questions (FAQs)

What happens if the undergraduate research project fails?

This question will most likely not be asked in quite this way. Undergraduate researchers wonder, "What if I fail?" Certainly, there are some instances in which student inaction or error may be the cause of a project's failure to reach its goals, but more likely the project "fails" because unexpected results, technical obstacles, or results that cannot be interpreted are part of the process. This lesson is important for students, and they need to understand the implications of "failure" (a word that mentors should avoid using). Mentors need to explain that not all research and scholarship succeed, even for faculty members. For example, in experiments, the results are what the results are. Perhaps the result is not what was expected or desired, but it may form the basis for the next project or send the researcher off in another direction altogether. Helping the student to sort out unexpected or contrary outcomes is an important task for a mentor.

On the other hand, if a project "fails" because a student is unmotivated and will not work hard, then a different dilemma for the mentor arises. A mentor should try to forestall this possibility by encouraging the student in the first week, making the expectations clear, checking in regularly with the student, and leaving the door open for questions and guidance. In unusual cases, even then a student may be unresponsive. In that case, letters of recommendation should reflect the student's lack of personal initiative. Fortunately, this is an uncommon occurrence.

How much can I ask of a student?

Students are generally curious and willing to work hard. Clear guidelines, a well-constructed statement of work, and open communication with the student will allow the mentor to adjust, either by increasing or decreasing, the expected pace based both on the student's skills and independence and on the nature of the project. Providing timely feedback to students enhances their productivity.

Do I have to be available all the time to be an effective mentor?

Establish regular contact hours when you know you will be available. In the first weeks, your presence will be an important influence on the direction of the project. If occasionally you cannot be present, assign someone to be available to answer questions or provide guidance.

How much guidance will a student require?

It depends entirely on the student and the project in which she or he is involved.

What does it take to be a good mentor?

The most important asset is the willingness to be a mentor. Be flexible, be patient, take the initiative, and be responsive. Plan for the experience and do what you can to make it a success.

Appendix B: Students' Quotes about Their Mentors and Their Research Experiences

These are responses from undergraduate students gathered after their research experiences in multiple disciplines, over the past 10 years.

As I work with my undergraduate students, I remember all of the time that (my mentor) spent working with me ... and how pivotal it was in my decision to pursue an academic career.

(My mentor's) contagious enthusiasm for research inspired me to pursue a graduate degree in science.

This experience has not only solidified my wish to attend graduate school but also has been the most educational experience of my college career.

(My mentor) has enabled me to learn from a hands-on perspective that reinforces much of the knowledge I gained through traditional classes, as well as challenging me to think at a more critical level that will be invaluable in graduate school.

First of all, (my mentor) has allowed me to do any project that catches my interest, letting me explore my passions and work on what I love. Along with this freedom, she has given me an incredible amount of support so I could take full advantage of it.

(My mentor) helped guide my ideas to concrete form and substance in the initial phases of the project and has directed me to the resources and paths of thought that have taken my research to new levels in new directions.

(My mentor) respects my academic abilities and has not only allowed me to take my project in the directions I chose, but has encouraged the developments I have made, which is a significant and too-often overlooked aspect of mentorship.

I learned how a dance can be used as a tool for social change and to think about movement in ways that are different from my previous experiences.

I was able to make connections with faculty that I would not have been able to make without this experience.

My project, in particular, has taught me to constantly reevaluate the things I hold to be true, and that this world is not static, giving us endless opportunities to learn about the new.

From working on my project, and watching other researchers around me, I have learned that success is a result of stamina, and answers often do not come easily.

Participating in research has given me a great sense of pride while giving me an opportunity to learn about new areas of interests and determine how to further my education.

It's exciting to find something that no one else knows and to share that knowledge.

I felt that the work I have put into my thesis was actually worthwhile; it was not just a long paper researching a topic that has already been heavily discussed among analysts. I felt as though my research was actually significant, that I have the potential to enter this field and contribute to the betterment of society.

I had the unique opportunity of sharing my original research with a variety of professors and scholars from (my region). It was the first time I felt as though I were no longer just a sociology student, but rather a sociologist.

(My mentor) is not only highly professional and a respected expert in his field, he is enthusiastic about my project and progress, and has always been available and willing to help me whenever I needed it.

Appendix C: Mentoring Tips for Faculty

- Remember that your goal is enhancing the educational and personal growth of the student.
- Be patient. Do not take students' abilities for granted.
- Tailor explanations of concepts to the student's level. Students often remark that mentors forget that "I am just a student."
- Encourage questions. Create an environment in which all questions are legitimate and are answered.
- Show enthusiasm and interest in the student and the project.
- Be available and accessible. Make time for students. Everyone is busy. If you agree to be a mentor, you need to take the time required to be supportive. Avoid distractions, such as phone calls and colleague visits during scheduled student meetings.
- Be ready. If you are not prepared when the student arrives, it does more than cause him or her to do "busy work" to kill time; it sends a message about how much you value the student and his or her contribution and worth.
- Set aside a regular time for mentor-student meetings. The frequency of such meetings will vary by discipline and by level of student.
- Talk about career plans with your students, and if appropriate, encourage students to consider graduate school. Many students, even very bright and capable students, do not feel able or worthy; sometimes they only have to be asked if they're considering graduate school to be encouraged to apply.
- Occasionally choose a different venue for meetings, such as a campus coffee shop. Students typically enjoy seeing the "human" side of their mentors. Remember that you are always a role model.
- Trust is more easily lost than gained
- Think about what you say to students. Be consistent; students do repeat to each other the things you say. Never rebuke a student in front of others.

Louise Temple is a professor in the Department of Integrated Science & Technology at James Madison University, where she teaches microbiology and conducts research with undergraduates into a pathogen affecting turkeys. Her recent work includes development of original research experiences in the classroom, focusing on younger students. She did her doctoral and postdoctoral work at the Medical College of Virginia and then taught at Drew University for 10 years before joining James Madison. She has been active in CUR for nearly 20 years and has been a biology councilor for six years.

Thomas Sibley is a professor of mathematics at St. John's University and the College of St. Benedict, where he has mentored dozens of undergraduate researchers in mathematics and mathematical biology. His own scholarship includes publishing two mathematics textbooks and a variety of papers. His Peace Corps experience teaching high-school mathematics in French in the Congo set him on his career path. After completing his PhD at Boston University, he taught at Cuttington University in Liberia before joining St. John's. He was a CUR councilor for nine years.

Amy J. Orr is an associate professor of sociology at Linfield College, where she teaches courses in the sociology of education, race/ethnicity, gender, and social policy. Her primary research focus is educational inequality, particularly issues involving race, gender, and family structure. She served as a CUR social science councilor from 2006–2009 and has written two articles for the *CUR Quarterly* on conducting interdisciplinary undergraduate research abroad. Orr has served as the senior thesis coordinator for the Department of Sociology & Anthropology at Linfield for the past seven years, and actively supports undergraduate research at the annual meetings of the Pacific Sociological Association.

ISBN: 0-941933-39-3